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Land Use After Mine Closure — Risk Assessment of Gold and Uranium Mine Residue Deposits on the Eastern Witwatersrand, South Africa

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Abstract

Elements from gold and uranium-bearing outcrops and mine residue deposits (MRDs) on the Witwatersrand are transported into the surrounding environment through the action of wind and water. The concentrations of some consequently become enriched relative to their average crustal abundances. The aim of this study was to provide a gold mining company (AngloGold Ashanti Ltd.), the provincial environmental regulator (Gauteng Department of Agriculture, Conservation and Environment - GDACE) and the local Municipality (Ekurhuleni Metropolitan Municipality - EMM) with a simple decision-support tool to aid in prioritising MRDs for mitigation and reaching agreement on safe and sustainable end land uses.

We used a numerical rating scheme for a risk assessment, which combined a number of parameters in two separate stages to calculate a risk index. The first stage involved the classification of hazards associated with MRDs while the second involved an assessment of receptor vulnerability. Selecting the EMM (1923 km^2) as a study site, we combined historical aerial photographs (1938 to 2003) with geographical and multi-spectral data in a Geographical Information System (GIS). The multi-spectral data were acquired in 2002 and 2003 by the TERRA satellite's Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) sensor. Thematic images for five mineral signatures that we considered indicators of different routes of contaminant transport were derived from the ASTER data.

We identified and classified MRDs according to type, status or footprint type, and then subjectively identified the hazards to land use based on a scientific literature survey. We selected acid rock drainage and dust as the major hazards and then utilised the findings expressed in the literature survey to assign ratings for the different classes of MRDs. For the vulnerability assessment, we identified proximity of MRDs to dolomites, watercourses, agricultural land and dwellings as critical, based on a combination of literature review, historical aerial photographs (which also allowed old sidewall failures to be mapped), and remote sensing of the mineral signatures (indicating potential contamination of surrounding land). Based on this approach, of the 287 MRDs identified, we classified 50% as being of lower-risk; 40% as of medium-risk; 10% of higher-risk and 0% as of very high risk. All 30 of the higher-risk sites were slimes dams. The results of this exercise can be used to support the selection of sites for quantitative risk-assessment, and to focus resources on the higher-risk sites for mitigation or remedial measures.

1 Introduction

The gold- and uranium-bearing deposits of the Witwatersrand basin took some 360 Ma to form during the Archaean Period, between 3074 and 2714 Ma ago (Robb and Robb, 1998). In addition to aeons of natural weathering, a hundred and twenty years of mining and mine residue deposition has resulted in the transport via wind and water of elements from mine residue into soils, watercourses and groundwater. The concentrations of sulphur, chloride, some metals and naturally-occurring radioactive materials (NORMs) are in consequence becoming enriched in sink areas (Coetzee, 1995; Winde, 2001; Tutu et al., 2003; 2008; Mphephu et al., 2004; Coetzee et al., 2006).

Contamination from multiple sources is widely dispersed across the entire Witwatersrand region (Sutton, 2008). Although concentrations of metals and NORMs are generally lower than those found on base-metal mines or high-grade uranium mill sites (Alloway, 1993), they exceed prescribed standards in some soils and wetland sediments (Rösner et al., 2001; Naiker et al., 2003; Joubert, 2007). The bioaccumulation of elements in the vicinity of MRDs (a generic term used in this report for waste rock dumps, sand dumps and/or slimes dams) has been demonstrated for roots of a pasture grass (Weiersbye et al., 1999), tree foliage and seeds (Weiersbye and Witkowski, 2003; Dye et al., 2008), native plant herbal remedies (Steenkamp et al., 2005), and some common wild plants and edible crops (Weiersbye and Cukrowska, 2008). However, whether a risk to consumers exists depends on many factors, including the mobility of elements in substrata (Tutu et al., 2008), the ability of a plant species to exclude elements, the chemical forms, amount consumed and physiology of the consumer.

Determining whether the risk exists as a result of exposure to contaminants of gold mine origin, as opposed to other factors such as land disturbance and urban emissions, is challenging. Elevated tissue metal concentrations have been detected in the organs of wildfowl from EMM (Van Eeden and Schoonbee, 1992), but this could not be directly attributed to mining emissions. In another study, the Sungazer lizard *Cordylus giganteus*, was found to exhibit similarly impaired body condition on both over-grazed rangelands and gold mine contaminated sites, despite animals and prey items having elevated tissue metal burdens only on the latter sites (McIntyre et al., 2008). Causality has, however, been demonstrated under laboratory conditions in a dose-dependent fashion by Haywood et al. (2004) for frog larval mortality in response to acid rock drainage (ARD) and elevated metal concentrations, and under field conditions by Weiersbye and Witkowski (2007), for seed production and fate in phreatophyte trees growing on ARD-contaminated groundwater.

The heath impact of mine residue dust is also of concern (GDACE, 2005; Department of Environmental Affairs and Tourism, 2006). Witwatersrand gold residue dust has historically been perceived as a nuisance (Annegarn et al., 1991), however, the effect of silica quartz nanoparticles in the lungs is not properly understood (Hoet et al., 2004) and to what extent gold tailings dust contributes to human metal ingestion and absorption has not been investigated in South Africa.

With the curtailing of gold mining on the Witwatersrand, mining land is being redeveloped. However, inappropriate developments, such as houses or farms, on MRD footprints and other contaminated sites could result in liabilities for the public and the closing mines. Avoiding built developments altogether and vegetating MRDs and footprints with unsuitable plant species, such as those for pastures and playing fields, can also increase risk through the creation of `attractive nuisances'. These encourage use by potentially vulnerable receptors such as grazing livestock and children.

This study was undertaken due to a lack of guidelines on safe land uses for contaminated footprints and other lands in the vicinity of MRDs, and in response to pressure to redevelop mine lands for residential and agricultural purposes after mine closure (EMM, 2005). We describe a first-order risk assessment of gold and uranium MRDs and the identification of vulnerable land uses in their vicinity, using publicly accessible data and a numerical rating scheme similar to DRASTIC, which was developed by the United States Environmental Protection Agency (US EPA) (Knox et al., 1993; Navulur and Engel, 1998). Using DRASTIC, Al-Adamat et al. (2003) compiled a risk index in two separate stages. The first stage involved an assessment of groundwater vulnerability by classifying a geographical area with regard to its susceptibility to contamination based on its physical conditions, which are independent of the land use; and the second stage involved the addition of risk factors based on land use. We applied the same concept but with land use as the vulnerable receptor and MRDs as the risk factor source.

There are hundreds of MRDs across the Witwatersrand containing some 6 billion tonnes of mine residue (Wymer, 2001) and covering a combined area of between 400 and 500 km^2 (Marsden, 1986). This makes conventional data collection for risk assessments laborious and expensive. However, use of remotely sensed data saves time and provides opportunities to study subjects at various landscape scales (Chevrel et al., 2003). A constraint to risk assessments using remote sensing is that the detection of hazards is only possible if each can be related to distinct characteristics (Werz and Hötzl, 2007). Of relevance to this study was the ability of ASTER to detect a number of minerals associated with gold mine waste deposits, dust and aqueous emissions, namely pyrophyllite, chlorite, jarosite, copiapite and a feature associated with uranium-bearing ores (Sutton et al., 2006).

2 Method

2.1 Study Area

The Eastern region of the Witwatersrand basin, *viz* the EMM of Gauteng Province, was selected for study because of the extent of gold and uranium mining over 120 years, the availability of remote sensing and geographical data, and the aforementioned pressures for land development. The EMM extends 45 km from west to east and 55 km from north to south, comprising an area of approximately 1923 km^2.

2.2 Background information

2.2.1 Locating and classifying mine residue deposits (MRDs)

We used aerial photography from 1938, 1964 and 2003 (Table 1) and the Chamber of Mines (CoM) of South Africa’s Mine Dump Index (CoM, 1966) to: locate MRDs; classify the type (waste rock dumps, sand dumps and slimes dams), status (active, dormant, reworking and footprint) and footprint type where applicable (paddocks, free-draining or developed); and identify side wall failures (Sutton et al., 2006; Sutton, 2008).

Table 1 Historical aerial photography

Area	Company	Date	Scale	Access
West and East Rand	South African Defence Force imagery. Chief Directorate: Surveys and Mapping archive imagery; Orthorectification by the Centre for Geographical Analysis, Stellenbosch University.	May to September 1938	1/18000	Council for Geoscience
Witwatersrand Mine Dump Survey	Aircraft Operating Co. (Aerial Surveys) Ltd. EMPR Services, Johannesburg archive imagery.	October and November 1964	1/9000	Chamber of Mines
East Rand	Unrecorded.	February 2003	-	EMM

2.2.2 Detecting mineral indicators of mine residue and associated contamination

We selected two well-known potential hazards for MRDs that are distinguishable using remote sensing; namely, mine tailings dust fallout and ARD (Sutton, 2008, and references therein). The feasibility of using airborne hyper-spectral remote sensing to detect primary and secondary minerals as artefacts of waste disposal and ARD on gold mine lands had previously been demonstrated (Weiersbye et al., 2006a). However, this technique is relatively expensive (compared to satellite multi-spectral) and the data is not publicly available, therefore we utilized ASTER images for this study. Nonetheless, advantage was taken of spectral and ground-truthing data acquired in a hyper-spectral campaign on smaller areas (data not shown, Margalit et al., 2006), and this enabled four minerals (pyrophyllite, chlorite, jarosite and copiapite), together with the spectral signature of crusts on uranium-bearing ores and mine evaporation pans (hereafter referred to as ‘mincrust’), to be mapped using the ASTER images (Heller, 2006; Sutton et al., 2006). Three of the four minerals (chlorite being the exception) were also found to be directly associated with MRD tailings. The mineralogical investigations of whether mincrust is actually a direct measure of a uranium mineral or of a co-occurring surrogate are incomplete (N. Margalit, unpublished). Nevertheless, although chemically undefined, mincrust is useful as it was found to be consistently associated with MRDs, tailings spills and moderately to highly contaminated sites (including natural reef outcrops), and was found to be absent from uncontaminated sites (Sutton, 2008).

2.2.3 Identification of pathways and receptors for contamination

Pathways and receptors were identified through a combination of literature review, remote sensing and statistical analyses. ASTER imagery was used to identify the mineral signatures across the landscape.

Thereafter, relationships between land use and mineral signatures were examined using contingency tables, standardised residuals, odds and odds ratios. Pyrophyllite and copiapite were also found to be associated with tailings dust deposition on large roofs, mincrust was also found to be associated with wetlands and contaminated irrigated lands (suggesting an aqueous pathway), and pyrophyllite, mincrust and jarosite were found to be associated with disturbed land (Sutton et al., 2006; Sutton, 2008).

We assumed that all MRDs are susceptible to wind erosion because physical covers have negligible presence in the study area and grass covers are short-lived on gold MRDs (Weiersbye et al., 2006b). Consequently, differential ratings for dust were only assigned between MRD classes and not between individual MRDs. A further assumption was that all gold and uranium mine residues in the EMM contain higher concentrations of pyrite, metals and NORMs than the surrounding lands, and no MRDs are lined. Thus, individual MRDs could be rated based on their proximity to aqueous pathways. The selected aqueous pathways were: (a) dolomitic substrata, which provide enhanced access for seepage to groundwater (Hodgson et al., 2001); (b) perennial and seasonal watercourses — because of the potential for water and sediment-borne transfer of contaminants (Naiker et al., 2003; Tutu et al., 2003; Winde, 2001); and (c) agriculture — although this land use is a receptor it can also constitute a secondary pathway for contaminants from water and soils into the diet of the general population (Jones et al., 1990; Joubert, 2007). Other receptors selected were informal and formal settlements and industrial areas.

2.3 Use of a Geographical Information System (GIS) and statistical analysis software

The Environmental Systems Research Institute (ESRI®) ArcGIS™ version 8.3 software, including ArcMap™, ArcCatalog™ and ArcToolbox™ with Spatial Analyst™ was used, to which we added both the PC-based Statistical Analysis System (SAS® Enterprise Guide® version 3.0.0., SAS Institute, Cary, NC, USA) and STATISTICA statistical analysis software (Sutton et al., 2006 – Figure 1).

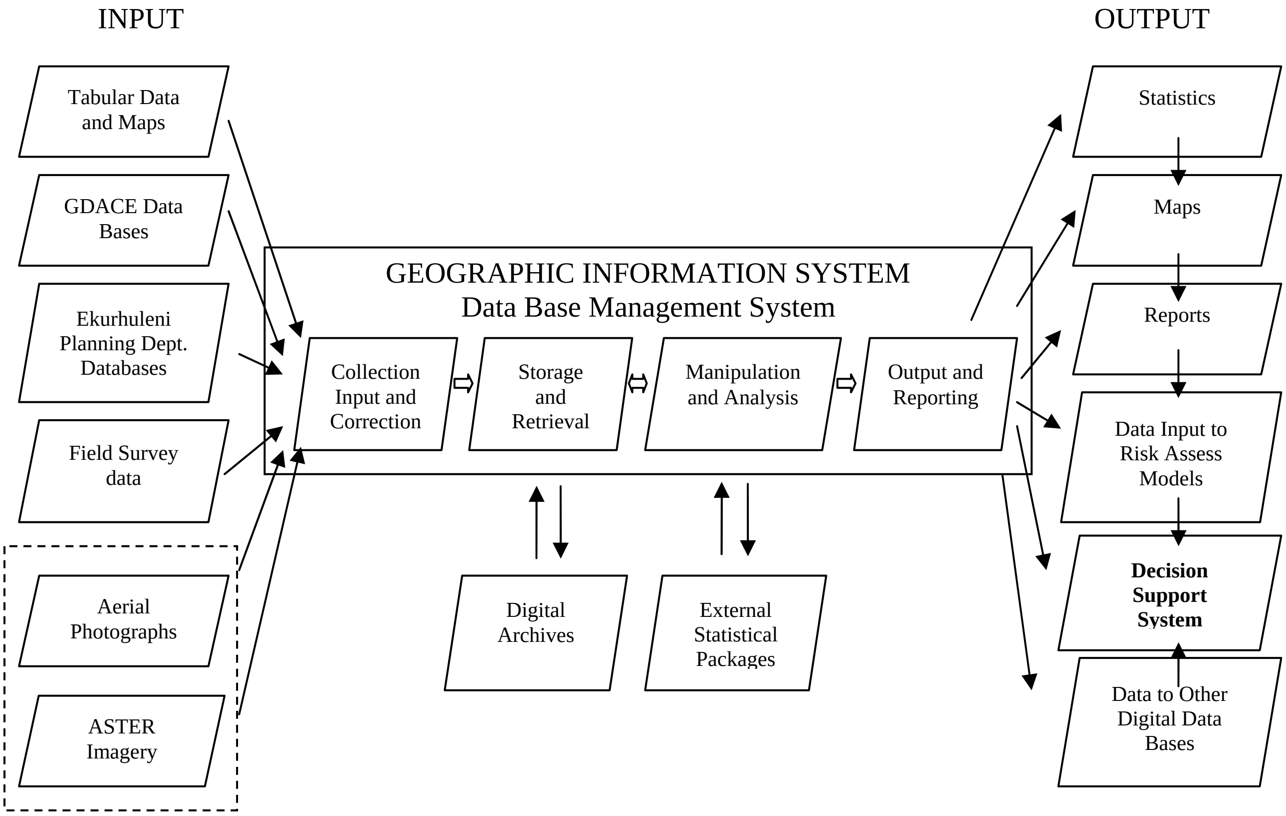

Figure 1 Risk assessment process using geographic information system (GIS) and remote sensing technology (modified after Foresman and Millette, 1997)

2.4 Risk assessment

The traditional view of risk assessment is of an objective process; however, judgement and value also form part of the process and the characterisation of risk must allow for stakeholder views (Fairman et al., 1998). For this study we utilised the views expressed in the scientific literature to assign relative ratings for hazard severity and receptor vulnerability ranging from 0 to 3; where 3 is high, 2 is medium, 1 is low and 0 is when there is no known hazard or vulnerability described. Although there is a substantial literature on ARD from MRDs on the Witwatersrand, there is little distinction made between different classes of MRD. When dealing with a variety of risks, a challenge is to determine the relative importance or ‘weighting’ of each one. Under these circumstances it is considered better to describe assumptions (and associated uncertainties) qualitatively rather than to ignore them (US EPA, 1998). We considered unmitigated hazards except where mitigation measures are considered the norm for a class of MRD, e.g. paddocks and trenches around active slimes dams reduce runoff when compared to a dormant dam. The risk assessment involved the following three steps.

2.4.1 MRD classification

The classification calculates the potential severity of the overall hazard posed by each MRD class by combining the relative ratings for each individual hazard (dust (d) and ARD (ard)) without weighting either one. Dust and ARD signature minerals were detected on many of the MRDs and on certain land uses in their vicinity, but the latter could not be assigned to specific sources. Thus the classification was also based on the literature, which was used to formulate assumptions (Appendix A), which may be questioned and modified when updating this assessment.

$$C = T + S + F + H \tag{1}$$

Where:

C is the classification.

$T = (d_t + ard_t)/2$ where $_t$ denotes the rating assigned to the hazard for MRD type (Table 2).

$S = (d_s + ard_s)/2$ where $_s$ denotes the rating assigned to the hazard for MRD status (Table 2).

$F = (d_f + ard_f)/2$ where $_f$ denotes the rating assigned to the hazard for MRD footprint sort (Table 2).

Table 2 Ratings allocated to selected hazards associated with class of mine residue deposit

MRD	Class	Hazard		Mean
		Dust (d)	ARD (ard)	
Type (T)	Rock	1	2	1.5
	Sand	2	3	2.5
	Slimes	3	3	3
Status (S)	Active	2	3	2.5
	Reworking	2	3	2.5
	Dormant	3	3	3
Footprint type (F)	Paddocks	2	2	2
	Developed	0	1	0.5
	Free-draining	1	2	1.5

H is evidence of historical slimes dam failure. Slimes dams that had failed were allocated a rating of H = 1 (rather than 3) because although some of the spillage will remain in the sediments and/or soil for a long period of time (Mphephu, 2001) we assumed that it has less influence than MRD class. Where no evidence of failure was observed, H = 0.

2.4.2 Determination of vulnerability

The vulnerability index is calculated by combining the ratings for environmental pathways and receptors.

$$V = D + W + A + R \tag{2}$$

Where:

V is the vulnerability index.

D is whether or not dolomite underlies part of the MRD (on dolomite = 3; off = 1).

W is related to proximity of the MRD to a watercourse (within = 3; <100 m = 2; >100 m = 1).

A is allocated according to distance of the MRD from agricultural land (within = 3; <500 m =2.25; >500 m but < 1,000 m = 1.5; >1,000 m = 0.75).

R is the combined rating for the receptor (i.e. land use). We examined informal settlements (IS), formal settlements (FS) and industrial areas (I) and derived ratings related to human exposure pathways for these land uses and distance from MRDs. For each land use the mean for human exposure pathways was calculated by rating each pathway between 0 and 3 (as described in 2.4 above) for the scenario that these land uses were taking place on the MRD or footprint, totalled and then divided by the number of potential pathways (i.e. 5) to provide a weighting ($_h$) between 0 and 3 (Table 3). We based our ratings on the assumption that small children may ingest contaminated soil when playing (EEA, 2002); children and the poor are most at risk and least able to cope with pollution threats (UNEP, 2002; EEA, 2002); the 1–2% of the population in EMM that rely on springs and rivers for domestic water (SSA, 2001) stay in informal settlements; food plants are grown in home gardens of the poor and in nearby sediments; and there is uptake of contaminants by some vegetable species in these home gardens (Weiersbye and Cukrowska, 2008).

Table 3 Weightings allocated to land use based on human exposure pathways for metals and NORMs

Exposure Pathway	**Informal Settlements (IS_h)**	**Formal Settlements (FS_h)**	**Industrial Areas (I_h)**
Ingestion of water	3	1	0
Inhalation of particulates	3	3	2
Ingestion of plant material	3	3	0
Ingestion of soil or dust	3	3	1
Skin absorption	3	1	0
Total	15	11	3
Weighting (total/5)	3	2.2	0.6

From this assessment we determined that industrial areas were lower vulnerability (i.e. <1) so they were excluded from the rating, thus:

$$R = (IS_h \times IS_d) + (FS_h \times FS_d) \tag{3}$$

Where ($_d$) is the weighting allocated according to the distance of the land use to the MRD, such that land-uses on the MRD or footprint were allocated the full rating, closer than 500 m were given 0.75, further than 500 m but closer than 1,000 m were given 0.5 and further than 1000 m received 0.25 (Table 4). We selected these broad distance categories based on the findings of Witkowski and Weiersbye (1998) for attenuation of soil pollution with distance around 56 slimes dam sites; anticipated metal solubility in highveld soils and sediments (Naiker et al., 2003), and because beyond 1000 m, tailings dust levels can no longer be distinguished from ambient air quality (GDACE, 2005).

Table 4 Vulnerability ratings assigned according to mine residue deposits proximity to land use

Land Use	Ratings at Different Distances from MRDs			
	0 m	< 500 m	< 1000 m	> 1000 m
Informal settlement (IS)	3	2.25	1.5	0.75
Formal settlement (FS)	2.2	1.65	1.1	0.55

2.4.3 Risk evaluation

The risk index is calculated by multiplying the outputs of the MRD hazard classification and land use vulnerability assessment. For this study the minimum possible risk index (to the nearest whole number) is 8 and the maximum is 99. This range was divided into four equal classes: 8–30 (lower risk); 31–53 (medium risk); 54–76 (higher risk); and 77–99 (much higher risk).

3 Results and discussion

Both informal and formal settlements emerged as higher vulnerability land uses (i.e. >2) in the presence of MRDs (Table 4). The impacts of extremes of acidity, salinity and metal exposure on flora and fauna are well established, and underpin environmental standards and regulations in many countries (Alloway, 1993). Under South African law, 'the precautionary principle' is embedded in the National Environmental Management Act (No. 107 of 1998) and therefore demonstration of human harm and causality is not necessarily required in order to justify changing land use in the vicinity of MRDs. It is requirement enough that reasonable concern exists as to the safety of a land use, and until that concern has been alleviated through quantitative risk assessments a risk-averse approach must be exercised.

The culmination of the exercise was a relative risk class and index for the MRDs (Appendix B) from which a 'risk map' was produced (Figure 2). Of the total 287 MRDs (including footprints) identified in the EMM (Sutton, 2006), 50% were classified lower-risk; 40% medium-risk; 10% higher-risk and 0% as much higher risk. The lower-risk MRDs were predominantly rock dumps, whereas the higher-risk MRDs were either slimes dams (27) or facilities constructed using slimes (three of – one water dam wall and two low-lying areas that had been in-filled). Of the former, three slimes dams were active, nine were dormant, twelve were being reworked and three were footprints (free-draining). The higher-risk MRDs were distributed evenly between on- and off -dolomite substrata; most (83%) were within watercourses and the remainder (17%) were within 100 m. For proximity to agriculture, 46% of the higher-risk MRDs were within 500 m; 17% were between 500 and 1000 m; and the remaining 37% were further than 1000 m.

The potential severity or consequence of the hazards posed by each MRD cannot be determined from aerial photographs and multi-spectral remote sensing alone, necessitating use of scientific literature. From the literature it became apparent that there are potential risks (particularly ARD related) associated with all gold and uranium MRDs and footprints. Thus, the distinction between higher, medium and lower-risk is to enable prioritisation of resources for more costly quantitative assessments that must precede the design of mitigation or remedial measures. With regard to identifying causal links between MRDs and contaminated areas using ASTER, the sensor is not sensitive enough to detect small areas (Rockwell and Hofstra, 2008), low concentrations of minerals, or potential minerals of interest, such as gypsum and iron oxides, due to the wide band-width (Bedell, 2004). These constraints prevented us from defining a zone of influence around individual or even groups of MRDs. Nevertheless, when combined with geographical data overlays the technique proved useful for a first-order risk assessment using generalised assumptions. Most importantly, the study enabled identification of vulnerable land uses affected via the aqueous pathway, which may require intervention through re-zoning, public education, remediation or other protective measures. Future involvement of stakeholders in determining the ratings and weightings will improve the risk assessment, as will weightings for MRD type, status, or footprint type. Furthermore, the findings can be tested by selecting a subset of sites from each category for quantitative analysis. New information can be incorporated into the assessment, through an iterative process, which will continually improve decision-making (US EPA, 1998).

4 Conclusion

The extent of gold and uranium mining, and heterogeneity of substrata and land uses, means that decision-making needs to be based on risk assessment at both the regional and site-specific scale. From a regional perspective, the use of remote sensing, GIS and a literature review during this assessment, has identified 30 of the 287 MRDs (i.e. 10%) as being of higher risk, thereby enabling prioritisation of resources. Dwellings and agriculture, in particular irrigated agriculture, were identified as vulnerable end land uses for MRD footprints or areas within the zone of influence of MRDs. Thus, when determining land uses and setting closure objectives in metal mining regions, residual and latent impacts need to be considered, and the potential for these impacts beyond the immediate site. Through so doing, future harm and liabilities can be avoided. Towards this we recommend the restriction of certain land uses on MRDs, footprints and polluted areas, and the implementation of buffer zones, pending quantitative environmental risk assessments.

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Figure 2 Map of environmental risk categories for mine residue deposits in the Ekurhuleni Metropolitan Municipality

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Appendix A Example of assumptions for rating hazards associated with class of mine residue deposit

MRD	**Class**	**Hazard**	
		Dust (d)	**ARD (ard)**
Type	Rock	Fine particles are washed into voids	Large inventories of fine particles and more permeable to oxygen than slimes dams (Pulles et al., 2005).
	Sand	No increase in ambient respirable dust but dust fallout is a nuisance (Annegarn et al., 1991)	Oxidation of surface layer for sand dumps is deeper than for slimes dams (Kempe, 1983; Marsden, 1986)
	Slimes	Easily eroded by wind (Blight, 2007)	
Status	Active	Wet	Inadequate seepage control
	Reworking	Wet	Disturbance increases pyrite oxidation (Tutu et al., 2003)
	Dormant	Dry	Inadequate seepage control
Footprint type	Paddocks	No vegetation	Ponding creates hydraulic head
	Developed	Covered surface	Recharge from neighbouring areas
	Free-draining	Site grassed	Grassing increases infiltration

Appendix B An example extracted from the GIS database constructed for mine residue deposits showing risk index and class

ID	Chamber of Mines No.	Mine Residue Deposit					Proximity of MRD to (m)				Risk	
		Type	Status	Footprint	Failure	Dolomite	Watercourse	Agricultural	Informal	Formal	Index	Class
256	-	Rock	Footprint	Develop	N/A	Off	>100	>1,000	>1,000	<500	10	Lower
287	-	Rock	Footprint	Develop	N/A	Off	>100	>1,000	<500	>1,000	11	Lower
231	-	Rock	Footprint	Develop	N/A	Off	>100	>500<1,000	>1,000	<500	12	Lower
282	-	Rock	Footprint	Develop	N/A	Off	<100	>1,000	>500<1,000	>500<1,000	13	Lower
221	-	Rock	Footprint	Develop	N/A	Off	>100	>1,000	<500	<500	13	Lower
241	-	Rock	Footprint	Develop	N/A	Off	<100	>1,000	>1,000	0	13	Lower
216	-	Rock	Active	N/A	N/A	Off	>100	>1,000	>500<1,000	>1,000	13	Lower
219	-	Rock	Active	N/A	N/A	Off	>100	>1,000	>500<1,000	>1,000	13	Lower
266	-	Rock	Footprint	Free draining	N/A	Off	>100	>1,000	>1,000	>500<1,000	14	Lower
283	-	Rock	Footprint	Develop	N/A	Off	>100	>1,000	0	<500	15	Lower
30	2628BC/L/3	Slimes	Dormant	N/A	No	Off	<100	<500	>1,000	>1,000	39	Medium
145	2628AB/L/19	Slimes	Reworking	N/A	No	Off	0	>1,000	>1,000	<500	39	Medium
185	2628AB/A/5	Sand	Dormant	N/A	N/A	Off	0	>1,000	>1,000	<500	39	Medium
194	2628AB/A/6	Sand	Dormant	N/A	N/A	Off	0	>1,000	>1,000	<500	39	Medium
50	2628AD/R/31	Rock	Reworking	N/A	N/A	On	0	>500<1,000	>1,000	<500	40	Medium
51	2628AD/R/29	Rock	Reworking	N/A	N/A	On	0	>500<1,000	>1,000	<500	40	Medium
86	2628AA/L/58	Slimes	Footprint	Paddocks	Yes	Off	0	>1,000	>1,000	>500<1,000	40	Medium
7	Post index	Slimes	Dormant	N/A	No	Off	>100	<500	>1,000	<500	40	Medium
72	2628AD/L/1	Slimes	Dormant	N/A	Yes	Off	0	<500	>1,000	<500	61	Higher
190	2628AB/L/26	Slimes	Reworking	N/A	Yes	Off	0	>500<1,000	<500	<500	61	Higher
24	2628AD/L/2	Slimes	Active	N/A	Yes	On	0	<500	>1,000	>1,000	62	Higher
37	2628AD/L/24	Slimes	Dormant	N/A	Yes	On	<100	>500<1,000	>1,000	<500	62	Higher
64	2628AD/L/22	Slimes	Footprint	Free draining	Yes	On	0	0	>1,000	<500	63	Higher
99	2628AB/L/35	Slimes	Reworking	N/A	Yes	On	<100	>1,000	<500	<500	63	Higher
125	2628AB/L/27	Slimes	Reworking	N/A	Yes	On	0	>1,000	>500<1,000	<500	64	Higher
33	2628AD/L/13	Slimes	Reworking	N/A	Yes	Off	0	<500	<500	<500	66	Higher
251	Cowles	Slimes	Dormant	Dam wall	N/A	On	0	<500	<500	>1,000	66	Higher
114	2628AB/L/36	Slimes	Dormant	N/A	No	On	0	>500<1,000	<500	<500	68	Higher